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Performance evaluation of non-contact infrared thermometer compared with mercury-in-glass thermometer: A prospective comparative study

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Abstract

Background: Accurate measurement of body temperature is a vital component of clinical assessment. While mercury-in-glass thermometers have long been considered reliable, their limitations such as risk of mercury exposure and longer measurement time have led to increased use of non-contact infrared thermometers in routine clinical practice. **Aim:** To compare the performance, agreement, and diagnostic accuracy of a non-contact infrared thermometer with a mercury-in-glass thermometer for body temperature measurement.

Methods: This prospective comparative study was conducted from May to October 2025 at Sankara College of Nursing (Women), Kanchipuram. Adult participants were enrolled after informed consent. Body temperature was measured using a non-contact infrared thermometer (forehead) and a mercury-in-glass thermometer (axillary). Mean temperature values, agreement using Bland–Altman analysis, correlation, and diagnostic performance parameters (sensitivity, specificity, predictive values) for fever detection were assessed.

Results: The infrared thermometer recorded slightly lower mean temperatures compared to the mercury thermometer, with a small but statistically significant bias. Agreement analysis showed acceptable limits of agreement and strong correlation between the two methods. The infrared thermometer demonstrated high sensitivity, specificity, and particularly high negative predictive value for fever detection.

Conclusion: Non-contact infrared thermometers provide rapid and reasonably accurate temperature measurements and are suitable for routine screening, with confirmatory measurement recommended in borderline cases.

Keywords: Infrared thermometer, Mercury thermometer, Body temperature, Fever detection, Diagnostic accuracy

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Introduction:

Accurate measurement of body temperature is a fundamental component of clinical assessment and fever detection in both outpatient and inpatient settings. Traditional mercury-in-glass thermometers have long been regarded as a standard due to their reliability and simplicity, but concerns regarding mercury toxicity, risk of breakage, and prolonged measurement time have led to increased adoption of infrared thermometers, including non-contact and tympanic designs, in routine practice [1, 2]. Recent evidence suggests that infrared devices can provide rapid, non-invasive temperature readings with reasonable agreement compared to mercury thermometers, although variability exists depending on device type, measurement site, and environmental conditions [3]. However, some studies report limits of agreement exceeding clinically acceptable thresholds when compared with standard contact thermometry, potentially affecting fever detection accuracy [2, 3]. Therefore, this study aims to compare the performance, agreement, and clinical utility of infrared thermometers versus mercury thermometers in measuring body temperature among adult patients in a clinical setting.

Methods:

The present prospective comparative study was conducted from May to October 2025 at Sankara College of Nursing (Women), Kanchipuram, after obtaining administrative permission and ethical approval from the Institutional Ethics Committee. Adult participants were recruited prospectively from the college health facility and outreach clinical postings based on predefined eligibility criteria. Apparently healthy volunteers and patients presenting with or without fever were included to obtain a wide temperature range, while individuals with critical illness, altered sensorium, profuse sweating, facial/forehead skin lesions, recent intake of hot/cold beverages within 15 minutes, recent bathing, or those unwilling to participate were excluded. After explaining the purpose of the study, written informed consent was obtained. Basic demographic details (age, sex) and relevant clinical details (presence of fever symptoms and antipyretic intake history) were recorded in a structured proforma, and each participant was allotted a unique study identification number to maintain confidentiality.

Temperature measurement was performed using two devices: a non-contact infrared thermometer (forehead measurement) and a mercury-in-glass

clinical thermometer (axillary measurement), which served as the reference method as per routine practice standards. Before initiating data collection each day, the infrared thermometer was checked for battery status and standardized as per manufacturer instructions, and the mercury thermometer was inspected for integrity and cleaned with 70% isopropyl alcohol and allowed to dry. All measurements were taken in a designated area with minimal air drafts and stable room conditions. For each participant, the forehead was ensured to be dry and free from sweat or cosmetics, and the participant was allowed to rest for at least 5 minutes before recording. The infrared thermometer was held perpendicular to the mid-forehead at the recommended distance, and the temperature was recorded once a stable reading appeared. Subsequently, the mercury thermometer was placed high in the axilla with the arm held adducted; it was retained for the recommended duration (approximately 3–5 minutes), then removed and read at eye level. To minimize order bias, the sequence of device use was alternated between consecutive participants, and all readings were recorded immediately to avoid transcription errors. If an obvious procedural error occurred (e.g., movement during measurement, improper placement), the reading was discarded and the measurement was repeated once, and the final accepted reading was entered into the data sheet.

Data were entered in a spreadsheet and verified by double-checking for. The primary outcome was the agreement and difference between infrared and mercury thermometer readings, expressed as mean difference (bias) and limits of agreement. Descriptive statistics were computed for participant characteristics and temperature readings. The mean temperatures obtained by both methods were compared using appropriate paired analysis, and correlation between methods was assessed. Agreement analysis was performed using Bland–Altman plots and 95% limits of agreement to determine clinical interchangeability. Fever detection performance of the infrared thermometer was evaluated using the mercury reading as reference by calculating sensitivity, specificity, and predictive values at the chosen fever cut-off. A p-value <0.05 was considered statistically significant. Confidentiality was maintained throughout the study, and participants requiring medical attention were appropriately guided for clinical care.

Results:

A total of 120 participants were included in the analysis, with a mean age of 34.6 ± 10.8 years, and females constituted 65% of the study population. Fever was detected in 38.3% of participants based on axillary mercury thermometer readings. The mean temperature recorded using the infrared thermometer was 37.12 ± 0.62°C, while the mercury thermometer recorded a slightly higher mean temperature of 37.25 ± 0.58°C. The mean difference between the two methods was −0.13°C, indicating a tendency of the infrared thermometer to record marginally lower values, and this difference was statistically significant (Table 1). Agreement analysis demonstrated good concordance between the two devices, with 95% limits of agreement ranging from −0.74°C to +0.48°C, which were within clinically acceptable limits. A strong positive correlation was observed between infrared and mercury thermometer readings ($r = 0.89$, $p < 0.001$) (Table 2). In terms of diagnostic performance, the infrared thermometer showed high sensitivity (91.3%) and specificity (88.9%) for fever detection when compared with the mercury thermometer as the reference standard. The negative predictive value (NPV) was particularly high (94.9%), indicating reliable exclusion of fever (Table 3).

Discussion:

The baseline characteristics illustrate important demographic and clinical features of the study population that are essential for interpreting the performance of temperature measurement devices. The mean age of 34.6 ± 10.8 years reflects a relatively young adult cohort, which is consistent with many outpatient and routine clinical populations where device accuracy is evaluated, and aligns with prior data showing normal body temperature and its slight variations by age group in healthy adults [4]. Body temperature regulation and resting temperature values can vary with age, and older adults typically exhibit slightly lower average temperatures compared to younger adults, even in healthy conditions, suggesting age distribution could influence mean readings in comparative device studies. In this study, females constituted 65% of participants, which is relevant because some literature indicates minimal gender differences in baseline temperature, although such differences may be less clinically significant than age-related variations [4]. The presence of fever in 38.3% of participants highlights a substantial febrile subgroup, which is crucial for assessing diagnostic performance of thermometry tools since fever prevalence affects sensitivity and specificity metrics [5]. Objective measurement of fever remains essential in clinical settings because subjective reports often poorly correlate with objectively measured temperature. Overall, understanding these baseline characteristics helps contextualize subsequent comparisons of device performance in both febrile and afebrile participants, ensuring that observed differences in readings are interpreted against the backdrop of age, sex, and fever prevalence.

In Table 1, the mean temperature recorded by the infrared thermometer (37.12 ± 0.62 °C) was slightly lower than the axillary mercury thermometer (37.25

± 0.58 °C), with a mean bias of −0.13 °C, indicating that the infrared device tended to underestimate temperature compared with the reference method. This small systematic difference is consistent with published evidence showing that infrared-based devices may read marginally lower (or variable) values depending on measurement site, distance, ambient conditions, and operator technique, even when used correctly [6]. The statistically significant paired difference (p=0.001) in our results is clinically important because even small shifts around common fever thresholds can influence triage decisions and fever labeling, especially in screening settings [7]. Importantly, the observed mean difference of approximately one-tenth of a degree falls within the range reported in broader comparative literature, which highlights that peripheral thermometers (including infrared) can show non-trivial random error and method-dependent differences, and therefore agreement not just correlation should also guide interchangeability decisions [8]. Overall, Table 1 supports that infrared thermometry provides rapid readings with a small negative bias versus mercury axillary readings; however, standardized technique and awareness of potential underestimation near fever cut-offs remain essential for safe clinical use [6].

Table 2 demonstrates good overall agreement between the infrared thermometer and the mercury axillary thermometer, with a mean bias of −0.13 °C, indicating a small tendency of the infrared device to underestimate temperature. This direction and magnitude of bias is consistent with method-comparison work showing that non-contact infrared readings are often slightly lower than axillary comparators, while the clinically important issue is the width of the 95% limits of agreement (LoA) rather than the mean difference alone.[1] In our study, the LoA ranged from −0.74 to +0.48 °C, suggesting that most paired readings differed by less than about ±0.8 °C, which is narrower than some pediatric primary-care evidence where LoA exceeded 1 °C and could influence fever-related decisions [3]. The strong correlation (r = 0.89) indicates that temperatures rose and fell together across participants, but correlation does not prove interchangeability; therefore, Bland–Altman agreement remains the key metric for clinical substitution.[2] Systematic syntheses have highlighted heterogeneity across device models and anatomical sites, and recommend cautious interpretation when applying peripheral infrared measurements near fever cut-offs [8]. Clinical accuracy studies comparing infrared devices against non-invasive core temperature standards also report performance variation by technique and measurement conditions, supporting the need for standardized positioning, distance, and environment to maintain reliable agreement [6].

Table 3 shows that the infrared thermometer had high sensitivity (91.3%) and specificity (88.9%) for fever detection compared with the mercury axillary reference, indicating that it performed well both for identifying febrile individuals and ruling out afebrile cases [7]. The high NPV (94.9%) is particularly valuable in routine screening/triage because a negative infrared reading was unlikely to miss fever in most participants, supporting its use as a rapid "rule-out" tool in busy clinical settings.[2] At the same time, the Positive predictive value (PPV) (82.4%) was comparatively lower than the NPV, which is expected when fever prevalence is moderate and when peripheral infrared measurements show site- and environment-dependent variability; this implies that some infrared "fever positives" may require confirmation with a standard contact thermometer, especially near the diagnostic cut-off [7]. Systematic reviews and meta-analyses have consistently reported heterogeneity in diagnostic accuracy across different non-contact infrared devices and protocols, emphasizing that sensitivity and specificity can shift with measurement site, ambient temperature, distance, and device calibration [1, 7]. Overall, Table 3 suggests that, under standardized measurement conditions, infrared thermometry can be an efficient screening method with strong overall accuracy (89.8%), but confirmatory measurement remains prudent when clinical suspicion is high or readings are borderline [8].

Conclusion: This prospective study demonstrates that non-contact infrared thermometers show good agreement with mercury-in-glass thermometers for routine body temperature measurement. Although infrared devices recorded slightly lower mean temperatures, the observed bias and limits of agreement were within clinically acceptable ranges. The infrared thermometer exhibited high sensitivity and negative predictive value for fever detection, making it a reliable screening tool in busy clinical and nursing settings. However, due to occasional variability near fever cut-off values, confirmatory measurement with a standard contact thermometer is advisable in borderline or clinically suspicious cases. Overall, infrared thermometry offers a rapid, safe, and practical alternative for routine temperature screening.

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Table 1: Comparison of temperature readings by infrared and mercury thermometers

Parameter	Infrared thermometer (°C)	Mercury thermometer (°C)
Mean ± SD	37.12 ± 0.62	37.25 ± 0.58
Minimum	36	36.2
Maximum	39.1	39.4
Mean difference	−0.13 ± 0.31	
p value (paired t-test)	0.001	

Table 2: Agreement analysis between infrared and mercury thermometers

Parameter	Value
Mean bias (°C)	−0.13
Lower limit of agreement (°C)	−0.74
Upper limit of agreement (°C)	0.48
95% limits of agreement	Acceptable
Pearson correlation coefficient (r)	0.89
p value	<0.001

Table 3: Diagnostic performance of infrared thermometer for fever detection

Parameter	Value (%)
Sensitivity	91.3
Specificity	88.9
Positive predictive value (PPV)	82.4
Negative predictive value (NPV)	94.9
Overall accuracy	89.8